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(54) **ANTI-THROMBOGENIC VENOUS SHUNT SYSTEM AND METHOD**

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(58) **Field of Classification Search** 604/8, 9, 604/10, 247, 500, 540, 109, 175, 891.1, 892.1; 600/561, 309

See application file for complete search history.

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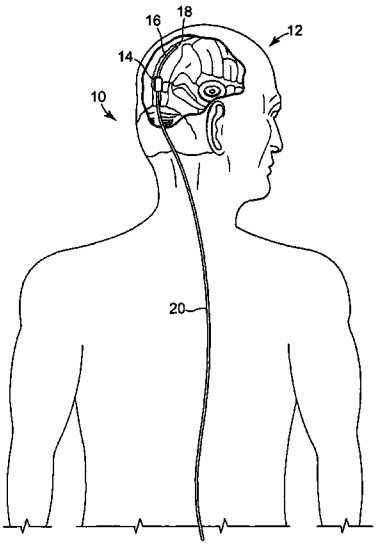
(57) **ABSTRACT**

A venous shunt system and method adapted to shunt cerebral spinal fluid in a patient. A fluid control device having a fluid passage is adapted to be placed allowing cerebral spinal fluid to flow through the fluid passage. A catheter having a lumen, the catheter being in fluid communication with the fluid control device. At least a portion of at least one of the catheter and the fluid control device being subjected to an anti-thrombogenic treatment.

18 Claims, 3 Drawing Sheets



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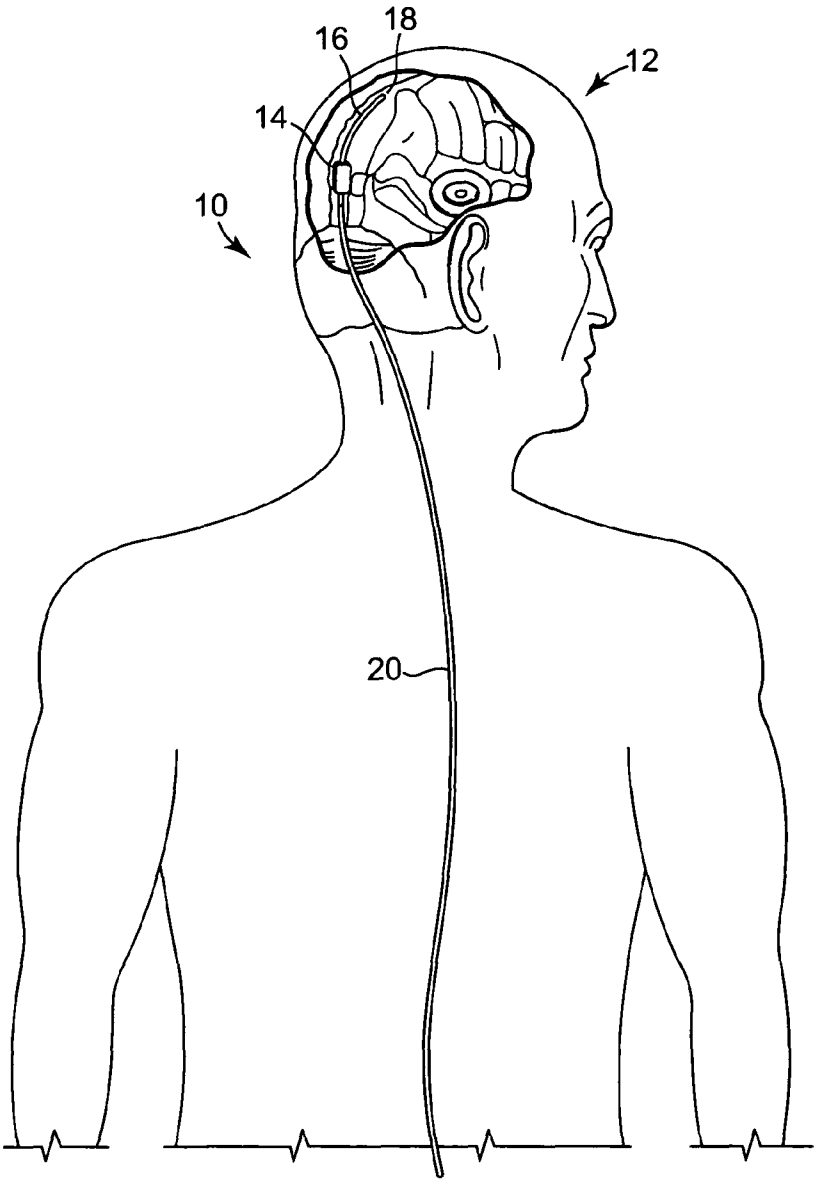

Fig. 1

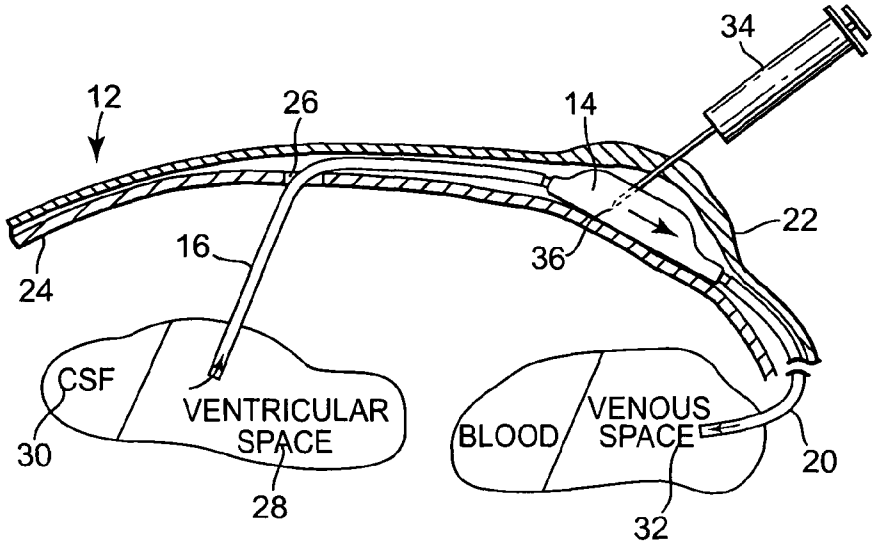
34
12
26
14
22
16
36
24
CSF
VENTRICULAR SPACE
BLOOD
VENOUS SPACE
20
30
28
32

Fig. 2

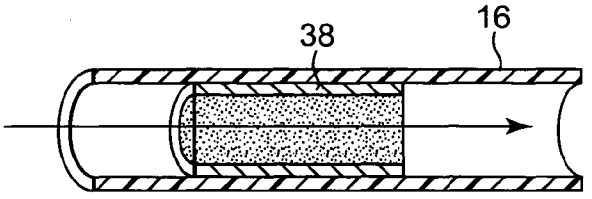
38
16

Fig. 3

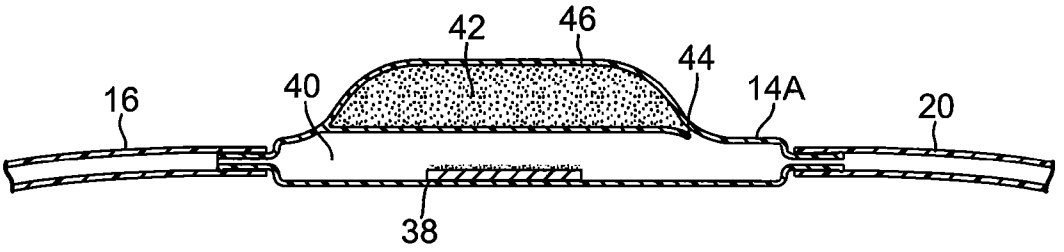

Fig. 4

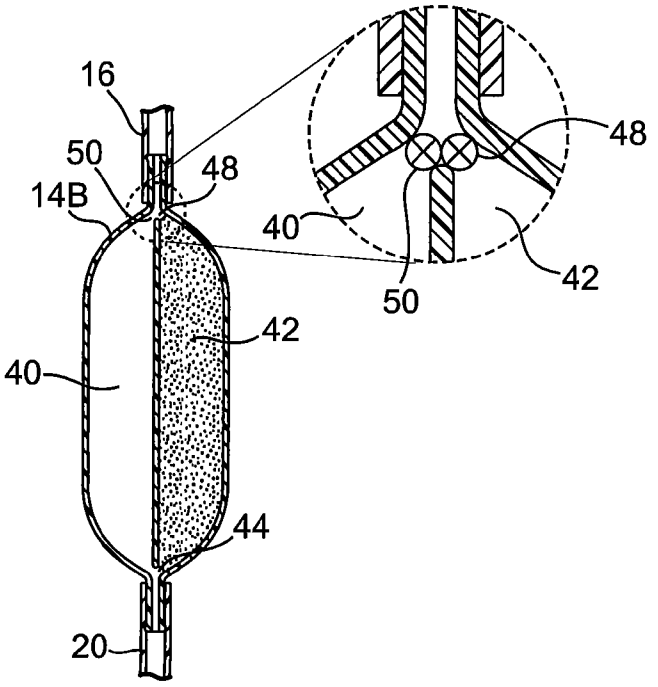

Fig. 5

ANTI-THROMBOGENIC VENOUS SHUNT SYSTEM AND METHOD

FIELD OF THE INVENTION

The present invention relates generally to the field of venous shunt systems and method and, more particularly, to venous shunt systems and methods used for treating hydrocephalus.

BACKGROUND OF THE INVENTION

Ventricles of the brain contain cerebrospinal fluid which cushions the brain against shock. Cerebral spinal fluid is constantly being secreted and absorbed by the body usually in equilibrium. Cerebral spinal fluid is produced in the ventricles of the brain, where under normal conditions, it is circulated in the subarachnoid space and reabsorbed into the bloodstream, predominantly via the arachnoids villi attached to the superior sagittal sinus. However, if blockages in circulation of cerebral spinal fluid, perhaps in the ventricles, cerebral spinal fluid can't be reabsorbed by the body at the proper rate.

This can create a condition known as hydrocephalus which is a condition marked by an excessive accumulation of fluid violating the cerebral ventricles, then the brain and causing a separation of the cranial bones. Hydrocephalus is a condition characterized by abnormal flow, absorption or formation of cerebrospinal fluid within the ventricles of the brain which subsequently increases the volume and pressure of the intracranial cavity. If left untreated, the increased intracranial pressure can lead to neurological damage and may result in death.

A common treatment for hydrocephalus patients has been the cerebrospinal fluid shunt. The standard shunt consists of the ventricular catheter, a valve and a distal catheter. The excess cerebrospinal fluid is typically drained from the ventricles to a suitable cavity, most often the peritoneum or the atrium. The catheter is placed into ventricles to shunt cerebral spinal fluid to other areas of the body, principally the peritoneum or alternatively to the sagittal sinus, where it can be reabsorbed. The presence of the shunt relieves pressure from cerebral spinal fluid on the brain.

A problem with venous shunt systems and methods is the possible complication of thrombus formation. A thrombus may form, for example, in the lumen of the shunting catheter or on the surface of the catheter. The same is true for a fluid flow device, e.g., a pressure or flow regulator, which may be included in the venous shunt system. Further, thrombus formation may occur near the area of the outlet tip the catheter, the so-called tip zone.

Formation of thrombus in or near the venous shunt system, whether in or on a component of the venous shunt system, could lead to blockage of flow and compromise the performance of the shunt system.

BRIEF SUMMARY OF THE INVENTION

Clogging or occluding of a venous shunt system may be prevented or corrected through the use of an anti-thrombogenic and/or clot busting agent or agents. The use of such agent or agents can be effective in preventing the formation of a thrombus or in the elimination of a thrombus already formed.

In a preferred embodiment, the present invention provides a venous shunt system adapted to shunt cerebral spinal fluid in a patient. A catheter, having a lumen, is adapted to be placed allowing cerebral spinal fluid to flow through the lumen. At least a portion of the catheter being subjected to an anti-thrombogenic treatment.

In another embodiment, the present invention provides a venous shunt system adapted to shunt cerebral spinal fluid in a patient. A fluid control device having a fluid passage is adapted to be placed allowing cerebral spinal fluid to flow through the fluid passage. A catheter having a lumen, the catheter being in fluid communication with the fluid control device. At least a portion of at least one of the catheter and the fluid control device being subjected to an anti-thrombogenic treatment.

In a preferred embodiment, the anti-thrombogenic treatment comprises an anti-thrombogenic agent delivered to a proximate area of at least one of the catheter and the fluid control device.

In a preferred embodiment, a bioresorbable matrix holds the anti-thrombogenic agent.

In a preferred embodiment, the anti-thrombogenic agent is impregnated into at least a portion of at least one of the catheter and the fluid control device.

In a preferred embodiment, at least one of the catheter and the fluid control device has a chamber for holding the anti-thrombogenic agent.

In a preferred embodiment, at least one of the catheter and the fluid control device has an anti-thrombogenic treatment surface modification.

In a preferred embodiment, at least a portion of at least one of the catheter and the fluid control device are treated with a hydrophilic agent.

In a preferred embodiment, the hydrophilic agent comprises hydrogel.

In a preferred embodiment, the hydrogel is covalently bonded to at least a portion of at least one of the catheter and the fluid control device.

In a preferred embodiment, the hydrogel is covalently bonded to at least a portion of at least one the catheter and the fluid control device using ultraviolet light.

In another embodiment, the present invention provides a method of shunting cerebral spinal fluid in a patient. A catheter is placed to allow cerebral spinal fluid to flow through the lumen. At least a portion of the catheter is subjected to an anti-thrombogenic treatment.

In another embodiment, the present invention provides a method of shunting cerebral spinal fluid in a patient. A fluid control device is placed to allow cerebral spinal fluid to flow through the fluid passage. A catheter is placed with a lumen in fluid communication with the fluid passage to allow cerebral spinal fluid to flow through the lumen. At least a portion of at least one of the flow control device and the catheter is subjected to an anti-thrombogenic treatment.

In a preferred embodiment, the subjecting step delivers an anti-thrombogenic agent to at least a portion of at least one of the flow control device and the catheter.

In a preferred embodiment, the delivering step holds the anti-thrombogenic agent in a bioresorbable matrix.

In a preferred embodiment, the delivering step impregnates at least a portion of at least one of the flow control device and the catheter with the anti-thrombogenic agent.

In a preferred embodiment, the subjecting step holds the anti-thrombogenic agent in a chamber separate from the lumen of the catheter.

In a preferred embodiment, the subjecting step provides at least a portion of at least one of the flow control device and the catheter with an anti-thrombogenic treatment surface modification.

In a preferred embodiment, the providing step treats at least a portion of at least one of the flow control device and the catheter with a hydrophilic agent.

In a preferred embodiment, the hydrophilic agent is a hydrogel.

In a preferred embodiment, the treating step covalently bonds the hydrogel to at least a portion of at least one of the flow control device and the catheter.

In a preferred embodiment, the treating step is accomplished with ultraviolet light.

In a preferred embodiment, the subjecting step injects an anti-thrombogenic agent to a proximate area of at least one of the flow control device and the catheter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cut-away perspective view of cerebral spinal fluid flow control device implanted into the cranium of a patient;

FIG. **2** is a cross-sectional side view of a venous shunt system having an anti-thrombogenic agent administered to the system;

FIG. **3** is a cut-away side view of a catheter useful in a venous shunt system having an anti-thrombogenic agent associated with a bioresorbable matrix;

FIG. **4** is a cross-sectional side view of a device insertable into a venous shunt system having a dome containing an anti-thrombogenic agent; and

FIG. **5** is a cross-sectional side view of a device insertable into a venous shunt system having a separate, valve-controlled reservoir containing an anti-thrombogenic agent along-side a clear flow chamber.

DETAILED DESCRIPTION OF THE INVENTION

Consistent and reliable drainage of cerebral spinal fluid from one area of the body to another, e.g., from a ventricle or ventricles of the brain to another region of the body such as the peritoneum pr sagittal sinus, can be desirable. A consistent and reliable drainage method and system can minimize the expense as well as trauma and inconvenience to the patient associated with cerebral spinal fluid revision surgery and can also lesson risk to the patient due to an inoperative cerebral spinal fluid drainage system.

FIG. **1** illustrates an embodiment of a cerebral spinal fluid shunt, or drainage, system **10** for draining cerebral spinal fluid from one area, preferably the ventricles of brain, of the body of patient **12** to another area of the body of patient **12**. Cerebral spinal fluid can preferably be drained to the peritoneum and/or atrium and, alternatively, to the sagittal sinus. Shunt system **10** may consist solely of a catheter having a lumen to transport cerebral spinal fluid or may consist, as illustrated in FIG. **1**, flow control device **14**.

Flow control device **14** may be located anywhere along the path of cerebral spinal fluid flow. For example, flow control device **14** may be located at or near the inlet for cerebral spinal fluid, e.g., at or near the ventricles, or may be located at or near the outlet for the cerebral spinal fluid, e.g., at or near the peritoneum.

Alternatively, flow control device **14** may be located as illustrated in FIG. **1** along the flow path between the inlet and outlet. In particular, by way of example, flow control device **14** may be near the cranium **24**.

Ventricular catheter **16**, having a lumen, is connects flow control device **14** to inlet location **18** in the ventricle of patient **12**. It is to be recognized and understood that other locations, other than inlet location **18**, can be used. Distal catheter **20** connects flow control device **14** with an outlet for cerebral spinal fluid, not shown, which preferably is in the peritoneum. It is to be recognized and understood that other outlet locations can be used. Examples of other possible outlet locations include the atrium and the sagittal sinus.

Although not required, flow control device **14** can help alleviate cerebral spinal fluid flow differential due to different positioning of the body. For example, when the body is supine, the difference in elevation between the inlet of ventricular catheter **16** and the outlet of distal catheter **20** may be relatively small. Thus, the pressure differential due to elevation between the inlet and outlet may also be relatively small. This may result in a relatively small flow rate of cerebral spinal fluid through shunt system **10**.

However, when the body is erect, for example, the difference in elevation between the inlet of ventricular catheter **16** and the outlet of distal catheter **20** may be relatively large. Thus, the pressure differential due to elevation between the inlet and outlet may also be relatively large. This may result in a relatively large flow rate of cerebral spinal fluid through shunt system **10**.

The presence of a flow control device **14** in shunt system **10** can help to stabilize the rate of flow of cerebral spinal fluid through shunt system **10** by limiting the higher flow rates associated with, for example, an erect position of the body. However, it is to be recognized and understood that the present invention has applicability regardless of whether or not a flow control device is actually desired and/or utilized. However, since it is envisioned that a flow control device is generally desirable in most circumstances, the discussion hereinafter will be mostly based upon the inclusion of a flow control device. The use or inclusion of a flow control device, however, is not required.

Clogging or occluding of venous shunt system **10** may be prevented or corrected through the use of one or more anti-thrombogenic and/or clot busting agent or agents. The use of such agent or agents can be effective in preventing the formation of a thrombus or in the elimination of a thrombus already formed.

The use of the term anti-thrombogenic agent refers to an agent that is effective in preventing the coagulation or clotting of cerebral spinal fluid or other fluids in or near shunt system **10**. An example of an anti-thrombogenic agent is heparin. The use of the term clot busting agent refers to an agent that is effective in clearing already existing clots or obstructions of cerebral spinal fluid or other fluids in or near shunt system **10**. An example of a clot busting agent is Streptokinase or Urokinase. Although it is recognized that an anti-thrombogenic agent may be different from a clot busting agent, throughout this specification, including the claims, the use of the terms anti-thrombogenic agent, clot busting agent, either or both, is considered to refer to either agents or both agents. For the purposes of this invention, the terms are considered interchangeable since their purpose is to prevent or clear clots and/or obstructions from the path of flow of cerebral spinal fluid in shunt system **10**.

FIG. **2** illustrates a cross-sectional view of an embodiment of the invention in which an anti-thrombogenic and/or clot busting agent is delivered, or in a preferred embodiment, injected into flow control device **14**. In this schematic embodiment, not drawn to scale, flow control device **14** is implanted underneath scalp **22** exterior of cranium **24**. Ventricular catheter **16** is tunneled between flow control device **14** underneath scalp **22**, through burr hole **26** into ventricular space **28** containing cerebral spinal fluid **30**. Distal catheter **20** is also tunneled subcutaneously between flow control

device **14** and venous space **32** providing an outlet for cerebral spinal fluid from ventricular space **28**.

Hypodermic needle **34** containing an anti-thrombogenic and/or clot busting agent is transcutaneously inserted with tip **36** positioned at a location where the injection of an anti-thrombogenic and/or clot busting agent would be effective in preventing or clearing an obstruction in cerebral spinal fluid shunt system **10**. In a preferred embodiment illustrated in FIG. **2**, tip **36** of hypodermic needle **34** is positioned within the body of flow control device **14** in order to deliver an anti-thrombogenic and/or clot busting agent to flow control device **14**. The presence of an anti-thrombogenic and/or clot busting agent in flow control device **14** can help avoid or clear obstructions that might otherwise jeopardize the effectiveness and/or reliability of shunt system **10**.

Alternatively, hypodermic needle **34** may be used to deliver an anti-thrombogenic and/or clot busting agent to other areas in or along the path of cerebral spinal fluid flow in or near shunt system **10**. As examples, an anti-thrombogenic and/or clot busting agent may be delivered by hypodermic needle **34** to a lumen in either of ventricular catheter **16** or distal catheter **20** or both. In another alternative embodiment, an anti-thrombogenic and/or clot busting agent may be delivered by hypodermic needle **34** to an area of ventricular space **28** near the inlet of ventricular catheter **16** or may be delivered by hypodermic needle **34** to an area near the outlet of distal catheter **20** in venous space **32**.

It is to be recognized and understood that other delivery mechanisms and methods, beyond the use of a hypodermic needle as illustrated in FIG. **2**, are contemplated as well.

FIG. **3** illustrates an alternative delivery mechanism and delivery method for the delivery of an anti-thrombogenic and/or clot busting agent to shunt system **10**. Bioresorbable matrix **38** is secured in the fluid flow path of shunt system **10**, for example prior to implantation. Bioresorbable matrix **38** is impregnated with an anti-thrombogenic and/or clot busting agent. Anti-thrombogenic and/or clot busting agent is graduated released from bioresorbable matrix **38** while shunt system **10** is in use thus preventing or clearing clots which would otherwise obstruct the flow of cerebral spinal fluid through shunt system **10**.

Bioresorbable matrix **38** is degraded biologically and may be constructed from a bioresorbable material such as the polylactic acid and lactic acid copolymers currently used in the MacroPore™ CMF™ products marketed by Medtronic, Inc., Minneapolis, Minn. In an embodiment, bioresorbable matrix **38** may be using a copolymer described in U.S. Pat. No. 4,916,193, Tang et al, Medical Devices Fabricated Totally Or In Part From Copolymers of Recurring Units Derived From Cyclic Carbonates and Lactides, the content of which is hereby incorporated be reference.

As illustrated in FIG. **3**, bioresorbable matrix **38** is positioned within a lumen of ventricular catheter **16**. Bioresorbable matrix **38** may also to positioned a lumen of distal catheter **20** or, alternatively, may be positioned within flow control device **14** and illustrated by flow control device **14**A in FIG. **4**.

FIG. **4** also illustrates an alternative delivery mechanism and method for an anti-thrombogenic and/or clot busting agent. Flow control device **14**A is similar to flow control device **14** having a flow chamber **40** with an inlet fluidly coupled to ventricular catheter **16** and an outlet fluidly coupled to distal catheter **20**. Also included in flow control device **14**A is a conventional fluid flow control mechanism which is not explicitly shown. Such flow control mechanisms, such as a tortuous path, however, are well know in the art.

A preferred fluid control mechanism is illustrated in co-pending U.S. Patent Application filed on even date herewith in the names of William J. Bertrand and Bill Sugleris and entitled "Implantable Cerebral Spinal Fluid Flow Device and Method of Controlling Flow of Cerebral Spinal Fluid", the contents of which are hereby incorporated by reference.

Flow control device **14**A differs from flow control device **14** by having a second chamber **42** that holds a supply of anti-thrombogenic and/or clot busting agent.

Second chamber **42** has an opening **44** permitting communication of anti-thrombogenic and/or clot busting agent from second chamber **42** into the fluid flow path of shunt system **10**, such as into flow chamber **40** of flow control device **14**A.

In a preferred embodiment, upper dome **46** may be flexible. Since flow control device **14**A may be implanted subcutaneously just under scalp **22**, pressure applied to scalp **22** can deform upper dome **46** forcing an amount of anti-thrombogenic and/or clot busting agent to flow from second chamber **42** through opening **44** into flow chamber **40** where the agent or agents can operate effectively to prevent or clear clots and obstructions.

While shown as part of flow control device **14**A, it is to be recognized and understood that second chamber **42** could also be part of a device separate from a device that provides flow control. That is, the flow control function of flow control device **14**A could be separate from the anti-thrombogenic and/or clot busting function of second chamber **42**. Flow control device **14**A could perform only an anti-thrombogenic and/or clot busting agent function and not a flow control function. Flow control could then, optionally, be provided in a separate device along the flow path of shunt system **10**, if desired.

FIG. **5** is a cross-sectional view of another embodiment of the present invention. Flow control device **14**B is similar to flow control device **14**A by having flow chamber **40** providing a main fluid path for cerebral spinal fluid and second chamber **42** for holding an anti-thrombogenic and/or clot busting agent. Preferably, anti-thrombogenic and/or clot busting agent is held in chamber **42** with a bioresorbable matrix as described above with respect to FIG. **3**. As with flow control device **14**A, opening **44** provides a path for communication of anti-thrombogenic and/or clot busting agents from second chamber **42** to the main fluid flow path of shunt system **10**.

Flow control device **14**B also has an opening or a one-way valve **48** positioned between a main fluid flow path of shunt system **10**, in this case either flow chamber **40** or ventricular catheter **16**, that will allow some of the flow of cerebral spinal fluid from ventricular catheter **16** to second chamber **42** forcing some of the anti-thrombogenic and/or clot busting agents from second chamber **42** through opening **44** into the main fluid flow path of shunt system **10**. Thus, a continuing supply of anti-thrombogenic and/or clot busting agent is available to shunt system **10** relying only on the flow of cerebral spinal fluid to dispense the anti-thrombogenic and/or clot busting agents.

Optionally a low-pressure opening valve **50** may be positioned in the flow path of flow chamber **40**. One-way valve **48** in this embodiment would have a higher, perhaps only slightly higher, opening pressure. Under normal, i.e., unobstructed, flow conditions, most or nearly all of the flow of cerebral spinal fluid would pass through flow chamber **40** with little or none of the flow of cerebral spinal fluid passing through second chamber **42**.

Upon buildup of back pressure due to downstream clotting or obstruction of cerebral spinal fluid flow in shunt system **10**, one-way valve **48** will either open or open further resulting in

a flow or increased flow of cerebral spinal fluid through second chamber **42** allowing the release, or release of greater amounts of, anti-thrombogenic and/or clot busting agents.

As with flow control device **14**A of FIG. **4**, it is to be recognized and understood that second chamber **42** could also be part of a device separate from a device that provides flow control. That is, the flow control function of flow control device **14**B could be separate from the anti-thrombogenic and/or clot busting function of second chamber **42**. Flow control device **14**B could perform only an anti-thrombogenic and/or clot busting agent function and not a flow control function. Flow control could then, optionally, be provided in a separate device along the flow path of shunt system **10**, if desired.

As can be seen, the anti-thrombogenic and/or clot busting agent may be delivered to shunt system **10** in a number of different manners. The anti-thrombogenic and/or clot busting agent may be injected, for example as described above with respect to FIG. **2**. The anti-thrombogenic and/or clot busting agent may be held in a bioresorbable matrix, for example as described above with respect to FIG. **3**. The anti-thrombogenic and/or clot busting agent may be held in a second chamber, for example as described with respect to FIG. **4** and FIG. **5**.

An anti-thrombogenic and/or clot busting agent may also be provided through a surface treatment modification of one or more surfaces of any or all of the components of shunt system **10**. In particular, one or more of the surfaces of shunt system may be made hydrophilic through the use of well known techniques and processes. In a preferred embodiment of the present invention, one or more surfaces of shunt system **10** is made hydrophilic through the use of hydrogel. It is preferred that the hydrogel be covalently bonded to surface of an element or elements of shunt system **10** and still more preferably that such covalent bonding be accomplished with ultraviolet light. Other bonding methods may also be employed.

Suitable hydrogels include those that are 70 to 80 percent water content by weight. In a preferred embodiment, polyvinylpyrrolidone (PVP or Povidone) is utilized. PVP is ionically neutral. In other embodiments, PEG/PEO (polyethylene glycol/polyethylene oxide), PAA (polyacrylamide) and/or PVA (polyvinyl alcohol) hydrogels may be used. Other hydrogels may also be employed.

Preferably, hydrogel is surface grafted using covalent bonding to the implant surface. Coatings are held in place with Van der Waals forces, hydrogen bonding, ionic bonding or mechanical attachment. Preferably, covalent attachment, which is much stronger, is used and may be accomplished using ultraviolet light or other methods.

This treatment is similar to ultraviolet linked polyvinylpyrrolidone utilized under the tradename "BioGlide" by Medtronic, Inc., Minneapolis, Minn., for a surface modification of silicone elastomer shunts for the reduction of bacterial adhesion. This technology is described in U.S. Pat. No. 4,722,906, Guire et al, Binding Reagents and Methods; U.S. Pat. No. 4,973,493, Guire et al, Method of Improving the Biocompatibility of Solid Surfaces; U.S. Pat. No. 4,979,959, Guire et al, Biocompatible Coating For Solid Surfaces; U.S. Pat. No. 5,002,582, Guire et al, Preparation of Polymeric Surfaces Via Covalently Attaching Polymers; U.S. Pat. No. 5,217,492, Guire et al, Biomolecule Attachment To Hydrophobic Surfaces; U.S. Pat. No. 5,258,041, Guire et al, Method of Biomolecule Attachment To Hydrophobic Surfaces; U.S. Pat. No. 5,263,992, Guire et al, Biocompatible Device With Covalently Bonded Biocompatible Agent; U.S. Pat. No. 5,512,329, Guire et al, Surface Treatment Preparation, and U.S. Pat. No. 5,741,551, Guire et al, Preparation of Polymeric Surfaces, the contents of all of which are hereby incorporated by reference.

Thus, embodiments of the anti-thrombogenic venous shunt system and method are disclosed. One skilled in the art will appreciate that the present invention can be practiced with embodiments other than those disclosed. The disclosed embodiments are presented for purposes of illustration and not limitation, and the present invention is limited only by the claims that follow.

What is claimed is:

1. A venous shunt system adapted to shunt cerebral spinal fluid in a patient, comprising:

a catheter, having:

a first fluid flow lumen and a second fluid flow lumen through which said cerebral spinal fluid flows, said first fluid flow lumen having a fluid flow lumen pressure;

a first lumen having a first lumen pressure and coupled to said second fluid flow lumen; and

a second lumen coupled to said first lumen and defined, at least in part, by a second lumen wall;

a low-pressure valve coupling said first fluid flow lumen to said first lumen, said cerebral spinal fluid flowing through said low-pressure valve when a difference between said fluid flow lumen pressure and said first lumen pressure is greater than a pressure rating of said low-pressure valve;

a one-way valve coupling said first fluid flow lumen to said second lumen, said one-way valve having a higher pressure rating than said low-pressure valve and allowing at least some cerebral spinal fluid to enter said second lumen when said difference between said fluid flow lumen pressure and said first lumen pressure is greater than said pressure rating of said one-way valve;

an anti-thrombogenic agent contained within said second lumen, said anti-thrombogenic agent being delivered to said first lumen when said cerebral spinal fluid enters said second lumen; and

wherein said second lumen is deformable when a force external to said venous shunt system is exerted on said second wall, wherein said anti-thrombogenic agent is delivered to said first lumen when said force is exerted on said second lumen wall.

2. A venous shunt system as in claim **1** wherein said anti-thrombogenic agent is delivered to a proximate area of said first lumen.

3. A venous shunt system as in claim **2** further comprising a bioresorbable matrix holding said anti-thrombogenic agent.

4. A venous shunt system as in claim **2** wherein said anti-thrombogenic agent is impregnated into at least a portion of said catheter.

5. A venous shunt system as in claim **1** wherein at least a portion of said catheter has an anti-thrombogenic treatment surface modification.

6. A venous shunt system as in claim **5** wherein at least a portion of said catheter is treated with a hydrophilic agent.

7. A venous shunt system as in claim **6** wherein said hydrophilic agent comprises hydrogel.

8. A venous shunt system as in claim **7** wherein said hydrogel is covalently bonded to at least a portion of said catheter.

9. A venous shunt system as in claim **8** wherein said hydrogel is covalently bonded to at least a portion of said catheter using ultraviolet light.

10. A venous shunt system adapted to shunt cerebral spinal fluid in a patient, comprising:

a fluid control device having a fluid passage adapted to be placed allowing cerebral spinal fluid to flow through said fluid passage; and

a catheter having a catheter lumen having a catheter lumen pressure, said catheter being in fluid communication with said fluid control device;

at least one of said catheter and said fluid control device having:

a first chamber having a first chamber pressure;

a second chamber defined, at least in part, by a second chamber wall and being fluidly coupled to said first chamber;

a low-pressure valve, wherein said first chamber is fluidly coupled to said catheter lumen via said low-pressure valve, said cerebral spinal fluid flowing through said low-pressure valve when a difference between said catheter lumen pressure and said first chamber pressure is greater than a pressure rating of said low-pressure valve; and

a one-way valve coupling said second chamber to said catheter lumen, said one-way valve having a higher pressure rating than said low-pressure valve and allowing at least some cerebral spinal fluid to enter said second chamber when said difference between said catheter lumen pressure and said first chamber pressure is greater than said pressure rating of said one-way valve;

an anti-thrombogenic agent contained within said second chamber, being delivered to said lumen when said cerebral spinal fluid enters said chamber via said low-pressure valve; and

wherein said second chamber is deformable when a force external to said venous shunt system is exerted on said second chamber wall, wherein said anti-thrombogenic agent is delivered to said at least one of said catheter and said fluid control device when said force is exerted on said second chamber wall.

11. A venous shunt system as in claim **10** wherein said anti-thrombogenic agent is delivered to a proximate area of at least one of said catheter and said fluid control device.

12. A venous shunt system as in claim **11** further comprising a bioresorbable matrix holding said anti-thrombogenic agent.

13. A venous shunt system as in claim **11** wherein said anti-thrombogenic agent is impregnated into at least a portion of at least one of said catheter and said fluid control device.

14. A venous shunt system as in claim **10** wherein at least one of said catheter and said fluid control device has an anti-thrombogenic treatment surface modification.

15. A venous shunt system as in claim **14** wherein at least a portion of at least one of said catheter and said fluid control device are treated with a hydrophilic agent.

16. A venous shunt system as in claim **15** wherein said hydrophilic agent comprises hydrogel.

17. A venous shunt system as in claim **16** wherein said hydrogel is covalently bonded to at least a portion of at least one of said catheter and said fluid control device.

18. A venous shunt system as in claim **17** wherein said hydrogel is covalently bonded to at least a portion of at least one said catheter and said fluid control device using ultraviolet light.

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